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THE DUCK SICKNESS IN UTAH.

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INTRODUCTION.

Since 1910, annual losses from disease of large numbers of wild ducks in the Salt Lake Valley have attracted much attention from sportsmen and others interested in waterfowl. Thousands of these birds find suitable breeding grounds in the marshes formed in the deltas of the rivers draining into Great Salt Lake, while the great extent of these areas and the abundant food supply found there attract vast hordes of others that pass in migration during spring and fall. Early reports of losses from disease among these birds were exaggerated in many cases, but it soon became evident that ducks were dying in such numbers as to make it a serious matter. In the first years the trouble was little understood. Various theories advanced as to its cause were one by one rejected. Local interest was greatly aroused, and many attempts at investigation were made. It was recognized that the problem was of great importance, as a serious mortality among wild ducks in Utah would soon be reflected in a diminution in their numbers in other regions, some perhaps far distant.

Dead ducks from the affected areas were sent in to the Biological Survey and were transmitted to the Bureau of Animal Industry for

NOTE.—This bulletin is a final report on an investigation of mortality among ducks and other waterfowl in marshes about Great Salt Lake, Utah. It is for the information of sportsmen and others interested in the conservation of game birds. A preliminary report was published in 1915 as Department Bulletin No. 217.

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study. Agents of that bureau also made investigations in the field. In order to determine, if possible, the cause of the mortality, a short preliminary examination of the affected areas was made in August, 1913, by an assistant from the Biological Survey, and in the following year work was begun in July and continued during the summer and fall of 1915 and 1916. A preliminary report covering the work of the first year was published in the spring of 1915.[1] The present bulletin covers the entire investigation in so far as is pertinent to a discussion of the conclusions reached.

HISTORY IN UTAH.

Sick ducks had been noticed in the Bear River marshes at the northern end of Great Salt Lake for many years, though the trouble is not known to have been serious until 1910. The fact that there were sick ducks previous to the severe outbreak in that year was not generally known, some overlooking it and others refusing to admit it. It is well established, however, that sick birds were present in small numbers. Several hunters and guides who have shot on these marshes for many hunting seasons have recalled that sick and dead birds were found at an early day. Twenty-five years ago the hunting season began on September 1, and in certain areas, as in the region known as the North Shore, it was not unusual to find many dead ducks on this date. Occasionally, sick birds were found, and in some cases the rushes were full of decaying bodies. These, however, apparently attracted little attention. Some of the early settlers in this region have reported sick birds at earlier dates.

A few ducks are known to have died on the New State Gun Club grounds at the mouth of the Jordan River in 1902 or 1903, and sick birds were first reported from the mouth of the Weber River at about the same time. Helpless teal, found on several occasions during 1904 in the tules on the Weber River marshes, near the North Shore Gun Club, caused comment among the hunters. There are no records of sick birds during the next four years, but in the summer of 1909 a few were found in the Jordan River marshes, and late in fall others were reported. These late fall birds, found when ice was closing the marshes, may have been affected with some other trouble. Many hunters considered them to be cripples that had escaped during the shooting season. It is said that a considerable number of sick birds were found during that summer on the Weber.

It was not until 1910 that attention was definitely directed to the duck sickness. The summer season of that year was dry and the water level of the rivers far below normal. In mid-July reports were current of a peculiar disease among wild ducks in the marshes

[1] Wetmore, Alex., Mortality among Waterfowl around Great Salt Lake, Utah; U. S. Dept. Agr. Bul. 217, pp. 1–10, pls. 3, 1915.

at the mouth of the Jordan River. As August passed the reports became more numerous, and later a few sick birds were noted at the mouth of the Weber. On September 5 about 50 ducks, dead or helpless, were noticed in the Bear River marshes by A. P. Bigelow, of Ogden, and within a week hundreds were found. At the same time the trouble increased in the other localities mentioned. Many thousand wild ducks died on both the Jordan and the Weber, while on the great mud flats in the Bear River delta the mortality is said to have been almost beyond belief. Dead birds rotting in the sun dotted the water in the shallow bays, and long windrows of bodies were blown up on the shore lines and against the rushes. The birds died in such great numbers, and the causes of the mortality were so obscure, that a strong prejudice arose against killing and eating ducks that were apparently healthy. The gun clubs in the Bear River area were not opened that year, and few ducks were killed elsewhere. Many persons were even afraid to be near or to handle the sick birds, and stories were told of people and domestic animals that had contracted disease through contact with the ducks. Large numbers of dead ducks were picked up by men hired for the purpose on the New State Gun Club grounds during this season. The birds were piled up in heaps and covered with lime, and many of these piles were still intact the following spring. With fall rains and a rise in the rivers, due to the turning in of the flow used for irrigation during the summer, conditions were ameliorated. A few sick birds were present as late as October 21, but soon all had disappeared.

In the Jordan River district the cause of the mortality was attributed to typhoid or some other obscure infection due to the presence of sewage in the water from the Salt Lake City drainage. In 1911 the sewer was continued beyond the marshes to a dumping ground on the lake front, so that sewage was in a large measure eliminated.

In 1911 the trouble began again late in summer and, while prevalent in the same marsh areas, was much less severe than during the preceeding year. As the sickness was considered infectious or contagious, effort was made to remove or bury all dead ducks lying in the water in the channels of the Weber River.

In 1912 conditions were more serious. The marshes about the New State Gun Club are supplied with water through a series of canals, and this year the water was diverted early in the season, so that the marshes were dry, driving out the birds; consequently few died here. The grounds were not flooded again until September 20, when preparation was made for the fall shooting. On both the Weber and Bear River marshes, however, conditions were bad, and attempts were made to clear the marshes of dead birds. W. O. Belnap states that about 30,000 birds were picked up on the Weber River flats, while on Bear River, from records kept by V. F. Davis, it is learned

that the bodies of 44,462 wild ducks were gathered and buried between August 22 and September 21.

In 1913 a few sick birds were noted in the Bear River marshes early in summer, but the trouble was not serious until September. On September 4 Joe Cook reported 600 or more dead birds on some recently flooded flats near the mouth of Channel 3. Three days later men were brought down to pick up the dead birds, and the work continued until September 26. In this period V. F. Davis records that 46,723 ducks were buried. Attempt was made to clean up only those birds lying in the open. These formed but a small part, so that the figures given probably represent less than 20 per cent of the birds that actually died. In gathering these birds men traveled over the soft mud of the flats. The dead ducks were speared with pitchforks and thrown into tubs or boats. Where the soil permitted, these bodies were buried in trenches dug for the purpose. Elsewhere they were piled up, covered with rushes, and finally mud was thrown on them. Some of these piles of bodies were still to be seen during the summer of 1916. In both 1912 and 1913 the sickness ceased shortly after the opening of the hunting season. During the first few days of October in those years sick birds were common, and hunters often set out helpless ducks in front of their blinds as decoys for the healthy birds.

In 1914 sick birds first appeared about July 1, and although the trouble developed to a considerable extent, conditions were much better than in any other year since 1910. Comparatively few birds were lost in the Jordan River marshes, but conditions were not so satisfactory on the lower channels of the Weber. On August 21 probably between 8,000 and 10,000 ducks lay dead along the north channel in a distance of 2 miles (Pl. I, fig. 1). At the same time many helpless birds were in the stagnant water, and a large number unable to fly walked off across the flats at near approach. Birds continued to die here until about September 20. On the Bear River marshes two sick birds were found on July 15, and others had been reported earlier. Sick birds were numerous on August 11, and by August 20 the trouble was at its height. The last sick bird for the season was seen on September 27.

In 1915 the Jordan River marshes were drained, and the ducks frequenting them were driven elsewhere. The season proved to be abnormally dry, and practically no water passed the irrigation dams across the rivers after the 1st of July. The broad flats at the mouth of the Weber River were entirely bare and remained so until fall. In the Bear River region North Bay was dry, while only a narrow channel led through South Bay to the lake. The major part of the ducks normally found here were forced to go elsewhere, and conditions were such that there were few sick birds among those that

remained. A few were found when the water rose in the fall, but it was estimated that not more than 500 birds died during the season.

During 1916 practically no sick birds were found on either the Jordan or Weber Rivers. On Bear River the first were noted on July 3, and the trouble was at its height by August 30, with no abatement until September 25. It was practically at an end before October 1, though occasional sick green-winged teal and spoonbills were noted until October 17.

REPORTS FROM OTHER REGIONS.

Around the shores of Owens Lake, Cal., Dr. A. K. Fisher, of the Biological Survey, found many dead eared grebes and shovellers in June, 1891. He estimated the number of dead grebes at 35,000.[1] In November, 1914, the writer found many birds of these same species, with a few individuals of others, dead in this locality. Apparently the cause of death was similar to that producing the duck sickness in Utah. Considerable numbers of grebes and ducks come to Owens Lake in the fall and remain through the winter. The greater part are said to die before the end of February and are cast up along the shore.

Sick ducks have been observed in the Tulare Lake basin for more than 20 years, according to Tipton Matthews, deputy game warden of Kern County. These birds were found around Goose Lake and on the Widgeon Gun Club grounds at Brown's Knolls when the water supply was low in summer. In 1909 sick birds appeared around Soleta Lake; and in 1910 many thousand ducks died on Soleta, Goose, Buena Vista, and Tulare Lakes. Sick birds were found in these areas during the three years following. Frank C. Clark, a special assistant of the California Fish and Game Commission, made an investigation into the sickness at Tulare Lake in the fall of 1913.[2] In 1914 Soleta and Goose Lakes were dry, and no sick birds occurred on Buena Vista Lake, which was filled with fresh water. Tipton Matthews and the writer estimated that in this year at least 15,000 birds, the greater part of which were pintails, had died on Tulare Lake. Long lines of bodies had washed up along low levees on the south shore, and dead birds were scattered across the drying flats or lay along the dikes where they had crawled out of the water. Since 1914 few sick birds have been known here.

From the Lake Malheur region, in Oregon, a malady apparently the same as the duck sickness of Great Salt Lake has been reported, and in 1916 and 1917 sick ducks were reported from Baca Lake, 35 miles south of Malheur Lake.

An outbreak that occurred at Lake Bowdoin, near Malta, Mont., in August and September, 1915, killed large numbers of shorebirds

[1] North American Fauna No. 7, pp. 12–13, 1893.

[2] Cf. Condor, XV, pp. 214–226, 1913.

and many ducks. A few birds were still affected after the 1st of October. Individuals examined at this time had the same malady as the ducks in Utah, but it can not be stated definitely that all had died from this trouble.

Sick birds in large numbers were reported in the Cheyenne Bottoms, near Great Bend, Kans., in 1914 and 1915. From information furnished by Dr. N. P. Sherwood and Dr. B. T. Clawson, of the University of Kansas, it would seem that these may have been suffering from some bacterial affection.

Other reports more or less indefinite have come from other regions in the West.

OUTLINE OF FIELD WORK.

A preliminary examination and study of conditions was begun by the writer in the Salt Lake Valley on July 12, 1914, and continued without interruption until October 30. Conditions on the Bear, Weber, and Jordan Rivers were studied thoroughly, and visits were made to the Willard Spur, Promontory Point at the southern end of the Promontory Range, and Locomotive Springs, a large isolated marsh area on the northern shore line of Great Salt Lake near Kelton. In connection with this work the writer visited the Tulare Lake basin, in California, from November 3 to 11, where he was assisted materially by Tipton Matthews, deputy warden of Kern County, whose services were made available through cooperation of the California Fish and Game Commission. Following this, conditions were studied at Owens Lake, Cal., from November 12 to 14.

In 1915 work was begun in Utah on May 15 and continued until October 25. As the investigations of the previous year had established that the affection was apparently identical in the three large areas involved, it was decided to carry on intensive work in one area and to visit the other regions when necessary. The marshes and shallow bays in the delta of Bear River at the northern end of Great Salt Lake, offered a great expanse in which conditions were varied and in which waterfowl were enormously abundant. A small temporary field laboratory was erected here, and pens and cages for use in experimental work were built as needed (Pl. IV, fig. 2). This year was unusually dry, and large areas were bare which were covered with water under normal conditions. The New State Gun Club marshes were drained by order of the club authorities early in the year and remained dry during the whole summer season. The entire volume of water in the lower part of the Weber River was taken out for irrigation, and the flats at its mouth were dry until fall. On Bear River the amount of water in the stream was greatly reduced, and large marsh areas, normally covered with from 1 to 10 inches of water, dried and baked in the sun. North Bay was dry, but a part of South Bay remained, and here many ducks congregated. Work was carried

on in the Bear River region until October 28. Lake Bowdoin, near Malta, Mont., where sick ducks had been reported, was visited from October 2 to 9. On August 25 the lakes and marshes west of Salt Lake City were inspected in company with J. C. Smith, of the State Fish and Game Commission. In October one visit was made to Promontory Point.

In 1916 the field laboratory on Bear River was opened on May 15. Experimental work begun in the previous years was carried on to completion, and a large number of birds were handled and studied. The Locomotive Springs marsh near Kelton was visited on August 29. Work terminated on Bear River on October 25.

Acknowledgments are due many organizations and individuals for kindly assistance rendered in many ways, without which the investigation could not have proceeded nor could much valuable information have been secured.[1] The Bureau of Chemistry has cooperated in making analyses of water, alkaline scale, and other material.

THE DUCK SICKNESS.

SYMPTOMS AND DESCRIPTION.

The symptoms of the duck sickness in large part indicate a paralysis of the nerve centers controlling the muscular system. In exercising their powers of flight birds exert a maximum amount of energy, and a decrease in these activities is one of the early indications of the duck sickness. Birds affected may be able to support themselves in the air for short distances only, or may have the wings entirely helpless. Between these two stages all intermediate conditions are found. The paralysis is most marked at first in the great pectoral muscles that direct the wing in its downward stroke. The smaller muscles that support the wing when folded also relax and allow the carpal joint to drop from its normal position, so that the wings in birds at rest droop from the sides of the body (Pl. II, fig. 2). In swimming the anterior wing joint drags in the water, often forcing the wing tips up conspicuously at an angle above the back.

With this affection of the wings the paralysis gradually spreads to the muscles of the legs. Birds become unable to support the body, though still able to swim. Some individuals, though apparently helpless, are able to make off at a great rate by aid of both wings and legs. In individuals of species that have the legs greatly developed and specialized, as the avocet and the black-necked stilt,

[1] Especial thanks are due to the officers of the Duckville Gun Club for living quarters in the clubhouse and to individual members for assistance in field work; to the Bear River Club for permission to use a tract of ground utilized in experimental work, and other facilities; to A. P. Bigelow, of Ogden, Secretary of the Bear River Club Co., for aid in many ways; to L. B. McCornick for valuable assistance; to V. F. Davis, superintendent of grounds of the Bear River Club, for information of value; to Clarence Adney, of Corinne, for assistance; to W. O. Belnap for aid in work at the mouth of the Weber River; to the New State Gun Club for quarters while working on the Jordan River marshes; and to the State fish and game commissioner for permits for shooting and handling birds as needed in the work.

these lower extremities become affected almost at once, and the bird sits on the full length of the tarsus instead of standing on the toes. These birds are unable to escape when approached, but struggle with beating wings to rise to a standing position. In a short time they sink on the breast in the mud and then are entirely helpless. In ducks and most other species, except the shorebirds just mentioned, the legs become affected more gradually. Individual ducks are able to swim for some time after they are unable to support the body in a standing position. Slowly the muscles become more helpless until, capable of slight movement only, the feet remain in normal position under the abdomen. Sick birds seem to sense this increasing helplessness, and, when able, endeavor to work their way out of the water on mud bars, or seek shelter, if available, in rushes or other aquatic growth.

In the next stage of the sickness the neck muscles weaken and the head is supported with difficulty (Pl. II, fig. 1). Birds remain quiet unless frightened, and when disturbed the head, with slight control, sways drunkenly from side to side. Finally the bird lies, unable to move, with the head prone on one side (Pl. III, fig. 1). At this point, if the individual is in water, death comes by drowning, but on land the bird may live for some time longer. Many, however, avert drowning by throwing the head on the back, where it lies in an unnatural position.

Affected individuals early show considerable difficulty in breathing, and as the trouble progresses this is more acute. Inspiration becomes increasingly difficult and may be spasmodic, while the number of respirations per minute is lessened. In a great majority of cases death comes from cessation of breathing due to paralysis of the muscles controlling this function. In some birds the muscles slowly become passive, until finally only those in the anterior thoracic region respond. The intake and outflow of air is slight, and on casual observation such birds might be considered dead.

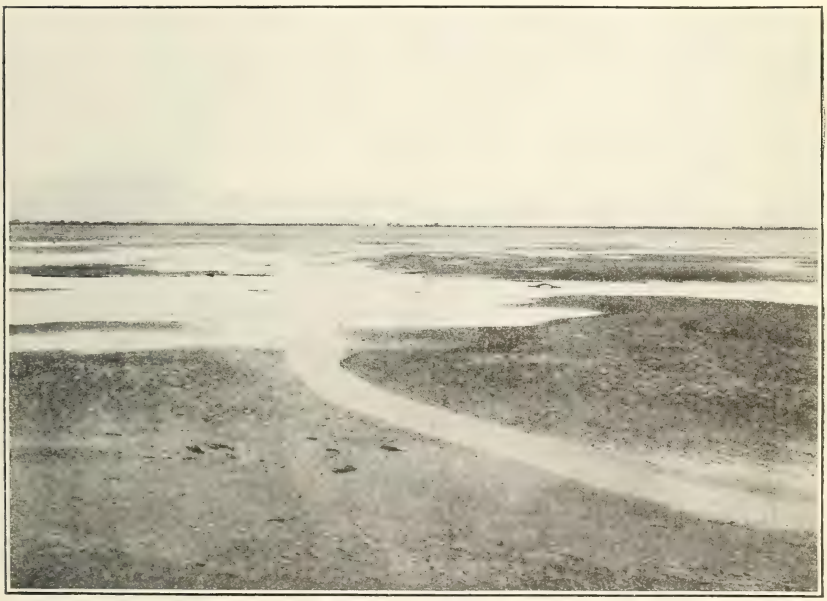
In severe cases the heart also is affected. Normally the pulse in a wild duck at rest and not unduly excited averages 120 beats per minute. With any struggling or attempt at flight it jumps at once to 180 or 200. In some severe cases of the duck sickness the heart action was weak and irregular. One mallard lived in the laboratory for two days with the heart beating only 30 times each minute and the respirations reduced to 8 for the same period. The body temperature (rectal) in sick birds remains about normal unless the heart is affected. With a decrease in the circulation the temperature falls slowly from the normal register of 104° F. to 109.8° F. (mean, 106.7°) to less than 100° F.

One important external symptom, easily overlooked, remains to be mentioned. Besides upper and lower eyelids birds possess a third

B15723

FIG. 1.—DUCKS DEAD FROM THE DUCK SICKNESS.

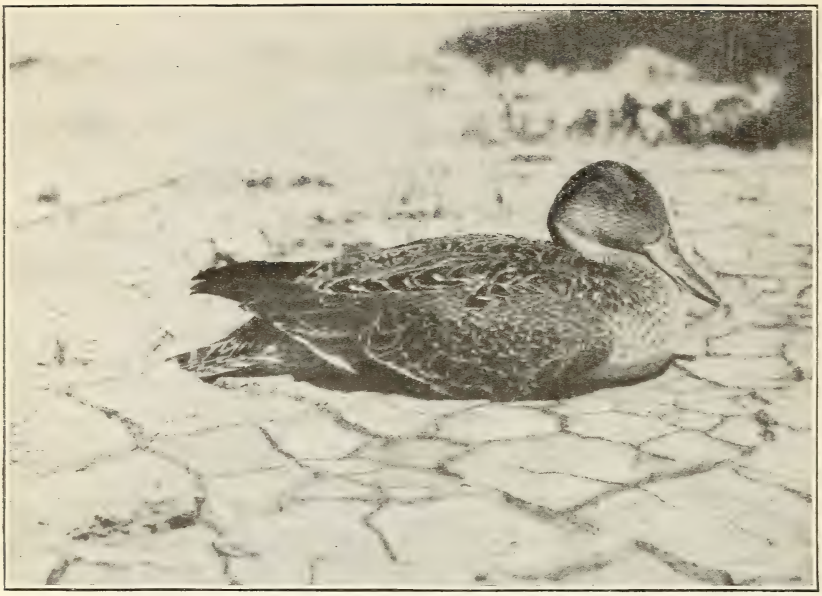
Photograph taken on the North Channel at the mouth of the Weber River, Utah.



B15730

FIG. 2.—VIEW OF DRYING MUD FLATS AT THE MOUTH OF BEAR RIVER, UTAH.

Ducks are made sick here by alkalis taken into solution when these areas are flooded by rising or shifting water.



B16261

FIG. 1.—PINTAIL WITH THE DUCK SICKNESS.

The eyes are affected, and the bird has difficulty in supporting the head.

B17114

FIG. 2.—CINNAMON TEAL UNABLE TO STAND.

The lower mandible hangs loosely and the wings droop from the sides.

B17111

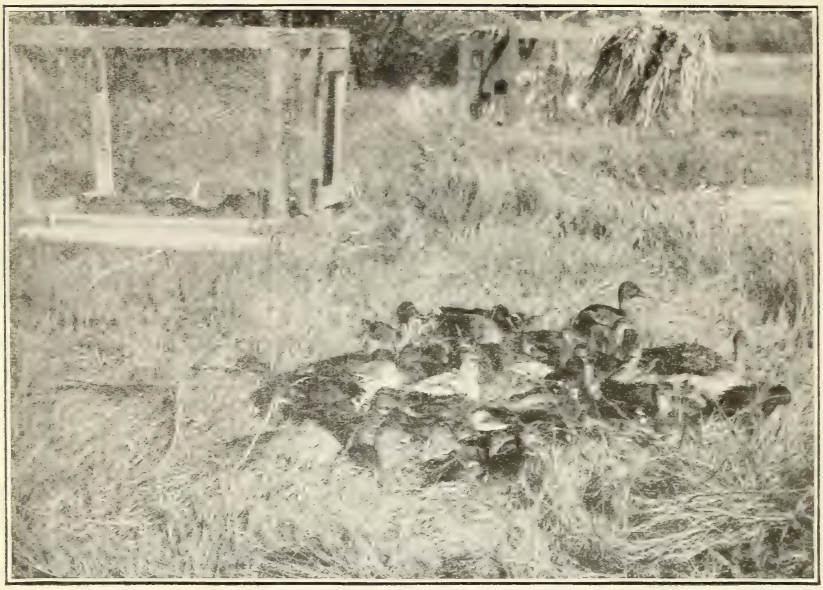
FIG. 1.—SICK MALLARD.

This bird was entirely helpless, but recovered under treatment.

B17123

FIG. 2.—GREEN-WINGED TEAL.

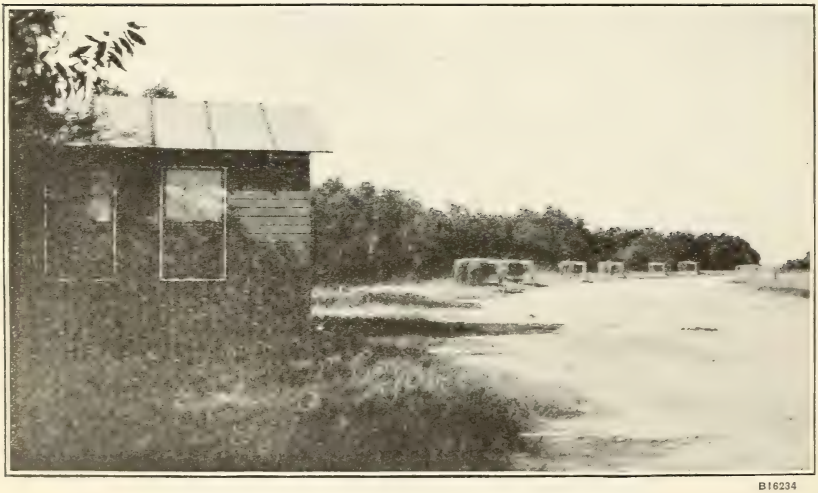
This figure illustrates a method of tying the wings of more active birds to prevent escape during handling.



B17146

FIG. 1.—GROUP OF SICK BIRDS.

These birds were collected on the Bear River Flats and now await transfer to pens.



B16234

FIG. 2.—ROW OF EXPERIMENT PENS AT MOUTH OF BEAR RIVER, UTAH.

The building is a temporary structure erected as a field laboratory. Other experiment pens in use at this time are not shown in the photograph.

eyelid, or nictitating membrane, that lies concealed at the lower angle of the anterior corner of the eye. In winking, this membrane is drawn rapidly back across the eyeball to the posterior corner. In birds with the duck sickness paralysis early affects the muscle (the pyramidalis) controlling this third eyelid, so that its action is more or less weakened. Winking is very slow at first, then the nictitating membrane can come back only part way across the rounded eyeball. Gradually the action of the muscle lessens, until finally the third lid lies motionless in its normal position at the anterior canthus of the eye. To test the activity of this membrane it is necessary only to hold the bird's head firmly and then with some slender object, as a bit of grass stem, a toothpick, the handle of a scalpel, or a pair of tweezers, to touch gently the eyeball near the posterior corner and observe the action of the third lid. When this is unaffected it will spring back at once, perhaps several times, in an effort to protect the sensitive surface of the eyeball. In birds with the duck sickness it operates as has just been described. This one reaction serves as a ready means of distinguishing the duck sickness from any other diseased condition of waterfowl known to the writer.

In connection with the symptom just described is another of interest. Lying within the orbit on the anterior surface of the eyeball is a large gland, known as the Harderian gland. This secretes a fluid that reaches the eyeball at its anterior corner below the nictitating membrane. In the duck sickness this gland always seems more or less affected and in most cases is considerably swollen, so much so, in fact, that the eyes are protuberant. Following this swelling the discharge of colorless, watery fluid from the gland becomes more copious. Normally it escapes at the anterior corner of the eye through two canals that unite and lead into the nasal chamber. In sick birds the secretion becomes greatly augmented, however, until these openings are not able to care for it, the eyes appear watery, and the fluid escapes between the lids. In some pintails kept under observation the escape of this fluid moistened the feathers of the entire side of the head. In a few hours this discharge becomes viscous and more or less opaque, and cements together the eyelids, while the augmenting supply held within puffs out the lids all around. The portion that escapes through the ducts passes through the inner nasal openings into the mouth. As the opening into the trachea (the glottis) lies immediately below, the fluid clogs it and interferes greatly with breathing. After two or three days the secretion becomes caked and cheeselike. When it thickens in large quantity it sometimes closes the trachea and causes strangulation. In a few cases the fluid penetrated to the bronchi, filling them completely and killing the bird. A severe irritation of the mucous membranes of the eye, including the nictitating membrane, is coupled with this discharge. In one case

under observation the nictitating membrane was enormously swollen and irritated, so that it distended both upper and lower lids and covered the whole eyeball except a small portion at the posterior corner.

The alimentary tract is found to be practically empty. The intestine is shrunken, firm, and hard to the touch, and much reddened, and on slitting and examining it closely the lining appears more or less irritated. The irritation is most marked in the first (duodenal) loop below the stomach, but may extend through the length of the small intestine as far as the cæca. This reddening of the lining of the canal appears sometimes in spots or patches or sometimes is continuous. Areas of irritation usually seem most severe at bends in the intestine. The gut contains a small quantity of mucouslike matter that is yellowish in color, and usually has flecks and clots of blood in it from ruptured capillaries. Ordinarily considerable gas is present. There is marked sloughing of the inner lining of the intestinal walls. Sometimes the blood content in the intestine is so large that the contained fluid is blackened. The cæca (in species having the cæca well developed) usually contain masses of broken-down and partly digested blood. The stomach lining between the lower end of the proventriculus and the hard grinding pads of the ventriculus is often softened and tends to slough. As digestion in birds is rapid, the stomach is soon empty of food and retains only gravel or hard seeds of the potato moss (*Potamogeton pectinatus*) and rush (*Scirpus paludosus*).

Other organs of the body appear normal. The ventricles of the heart are found to be in systole. The blood has a tendency to remain fluid, a condition sometimes holding for 10 or 12 hours or more after death.

The feces are loose and watery, more or less greenish, and are voided at frequent intervals. In helpless birds the feathers about the vent become dirty, and often the feathers covering the entire posterior portion of the lower surface of the body are stained green. The sphincter muscle closing the anal opening is relaxed, and little or no fluid is retained by the cloaca. The mucous membranes of the anus are irritated. As ducks sicken rapidly, when first affected they are usually very fat, and if the attack is not immediately fatal they subsist on this stored-up energy. Therefore, after two days the ordure shows a marked increase in the white matter thrown off by the kidneys. Ultimately this constitutes almost the entire excrement. As the renal matter is almost solid, it often clogs the cloaca and, compacting in a hardened mass, closes the anal opening entirely. These indurated masses are acid in their nature and serve still further to irritate the mucous membrane of the cloaca.

Among the species of ducks affected the green-winged teal has the least resistance to the malady. Field observations have shown that these teal may become severely affected in from 6 to 12 hours. The

larger ducks succumb more slowly. One or two days may elapse after an outbreak of the sickness before many pintails or mallards are found, though sick teal may have been present in abundance during the interval. In herons and ibises the poison may be more or less cumulative in its effect, as the birds seem to sicken slowly.

Sick birds are apparently in little pain in most cases and appear drowsy and lethargic, though alert at the approach of danger. Unless death comes through drowning there is little struggle. Dead birds lie on the breast with the feet in position under the body. The wings hang loosely at the sides, and the head reposes on one side in front. The tail is relaxed, and the feathers about the anus usually are stained with green from the feces.

AREAS WHERE SICK BIRDS ARE FOUND.

There are three areas in Utah which have been of importance in connection with the duck sickness. These may be defined roughly as the marshes near the mouths of the Jordan, Weber, and Bear Rivers, all located along the eastern shore of Great Salt Lake. Reports have come of sick birds from Utah Lake, but these must refer to some other ailment. On the Jordan River sick birds have been confined almost entirely to marshes and flats immediately at the mouth of the river. There are no certain records known to the writer of sick birds from the series of channels, small lakes, and marshes extending to the south, and lying between Salt Lake City and Garfield. On the Weber River there is little true marsh growth, the water passing to the lake in two main channels. Sick ducks occur along the north channel and for about 2½ miles inland from the lake front. In the Bear River region, sick birds are found on the two large shallow bays that receive the drainage of the river. In addition they occur on the Willard Spur, an arm of Bear River Bay, and in the shallow artificial lake, known as Chesapeake Bay, between Corinne and the gun clubs at Duckville. Affected birds occur at times in the Flume Pond just west of Corinne, and in the Salt Creek marshes, a marsh area formed by saline springs in the basin northwest of Little Mountain.

In all these regions the soil is strongly impregnated with saline matter. A large part is barely above the present lake level, and in no case is the land elevated more than a few feet. During the high-water level of 40 years ago all these areas were covered by Great Salt Lake itself.

SPECIES AFFECTED.

It was found from observation in the field that individuals of any species of bird that fed or drank in the shallower portions of the bays, whether habitually or occasionally, were liable to contract the sickness. The shallow-water, or river, ducks were more liable to it and

died in far greater numbers than any of the others; the green-winged teal seemed to have the least resistance, and the pintail was a close second; while mallards, spoonbills, and cinnamon teal died in smaller numbers. The redhead was the only member of the group of deep-water ducks that suffered to any extent, though ruddy ducks were found dead occasionally. Sick gadwalls and widgeons were seldom found. Among the great group of shorebirds, avocets and stilts perished in great numbers, but only occasional individuals of other species were found. In some years the avocets on the Bear River marshes were almost exterminated. In 1915 a great number of immature snowy herons perished, and annually a number of sick white-faced glossy ibises were observed. California and ring-billed gulls were common among the sufferers, and many sick and dead coots were found. Land birds were found sick only occasionally.

The trouble was not entirely restricted to birds, as occasionally muskrats were affected, and frogs (*Rana pipiens*) that apparently had died from this cause were found at times. On Tulare Lake great numbers of predacious diving beetles (*Cybister* sp.) were cast up with the dead birds. Other large beetles (*Dytiscus* sp.) of the same family were found dead or in a more or less helpless condition several times in the Utah marshes. Circumstantial evidence might indicate that these were affected as were the other animals.

In all, 36 species of birds were found that unquestionably had contracted the so-called duck sickness. Thirty-five are listed on field observations made by the writer, and one, the horned lark, is included on the authority of W. H. Meal, of Ogden. Sixteen other species of birds were found under such conditions as to indicate that they had died from the same trouble. The following list, arranged in systematic order, includes only those known certainly to have been affected:

Western grebe (*Æchmophorus occidentalis*).
Eared grebe (*Colymbus n. californicus*).
California gull (*Larus californicus*).
Ring-billed gull (*Larus delawarensis*).
Forster tern (*Sterna forsteri*).
Black tern (*Hydrochelidon n. surinamensis*).
White pelican (*Pelecanus erythrorhynchos*).
Mallard (*Anas platyrhyncha*).
Gadwall (*Chaulelasmus streperus*).
Widgeon (*Mareca americana*).
Green-winged teal (*Nettion carolinense*).
Cinnamon teal (*Querquedula cyanoptera*).
Spoonbill, or shoveller (*Spatula clypeata*).
Pintail (*Dafila a. tzitzihoa*).
Redhead (*Marila americana*).
Ruddy duck (*Erismatura jamaicensis*).
Canada goose (*Branta canadensis*).
White-faced glossy ibis (*Plegadis guarauna*).
Snowy heron (*Egretta t. thula*).
Coot (*Fulica americana*).
Avocet (*Recurvirostra americana*).
Black-necked stilt (*Himantopus mexicanus*).
Long-billed dowitcher (*Macrorhamphus g. scolopaceus*).
Pectoral sandpiper (*Pisobia maculata*).
Least sandpiper (*Pisobia minutilla*).
Red-backed sandpiper (*Pelidna a. pacifica*).[1]
Western sandpiper (*Ereunetes mauri*).
Marbled godwit (*Limosa fedoa*).
Lesser yellow-legs (*Iliornis flavipes*).
Killdeer (*Oxyechus vociferus*).
Horned lark (*Otocoris alpestris* subsp.).
Magpie (*Pica p. hudsonia*).
Yellow-headed blackbird (*Xanthocephalus xanthocephalus*).
Rusty blackbird (*Euphagus carolinus*).[2]
Cliff swallow (*Petrochelidon l. lunifrons*).
Pipit (*Anthus s. rubescens*).

[1] Found at Tulare Lake, Cal.

[2] Found at Lake Bowdoin, Mont.

UNTENABLE THEORIES ADVANCED.

Interest in the duck sickness has been so great among sportsmen and others that many theories as to its cause have been propounded. One of the first and most important attributed it to a disease of bacterial or protozoan origin. A few birds examined early in the outbreak revealed many coccidia, and for a time these were considered the causative agents of the disease. Later investigations, however, did not support this, and all efforts to find and isolate an organism capable of transmitting the trouble from one bird to another failed. For a brief account of the investigations made by the Bureau of Animal Industry the reader is referred to the preliminary report.[1]

Superficially the duck sickness presents many resemblances to avian cholera. Examination of many hundreds of specimens by the writer failed, however, to show any lesions whatever in the viscera (except the irritation in the intestine that has been described). Many blood smears were examined from the peripheral circulation and the heart, with no result. In addition, a large number of experiments were made in attempting to transmit the trouble. Healthy birds were confined with sick birds or were given grain treated freshly with feces taken from affected individuals. Some were fed forcibly on fragments of organs or the entire stomach and intestinal content of sick birds. The mucous lachrymal discharge in birds far gone was transmitted to the eyes of some. Intravenous and hypodermic transfusions of blood were made. All these experiments gave negative results. It has been said that domestic fowls are very susceptible to the duck sickness. Attempts to transmit the trouble to hens were without effect.

During three field seasons many hundreds of wild ducks were kept in confinement. After the nature of the trouble was understood (in 1914) healthy and sick birds were confined in the same pens continually, with no attempt to avoid possible transmission of the trouble, and in no instance did any of the normal birds contract the sickness. Sick birds were handled constantly by the writer and his assistants, but in no case did ducks or other birds tamed and kept as pets around the laboratory contract the trouble. A young great blue heron, reared by hand in 1916, was, with no ill effect, fed often on the flesh of birds that had died from the duck sickness. This same year a considerable number of young wild ducks were reared for use in experiments. Once or twice a week these birds were fed a bran mash containing a quantity of meat. When fresh fish were not available, the bodies of ducks and other birds newly dead from the duck sickness were ground up and fed to them, with no harmful result. If the sickness had been contagious or infectious, cases would have resulted under such treatment.

[1] U. S Dept. Agr., Bul. 217, p. 5, 1915.

Another theory that attracted much attention was the supposition that the birds were poisoned by sulphurous or sulphuric acid resulting from waste from the great smelters near Salt Lake City. It was believed that sulphur from the smelter smoke, depositing on vegetation, was washed into the streams and marshes by rains, and that in combination with moisture it formed sulphurous and sulphuric acid. It was supposed that the ducks in feeding found this in quantities sufficient to be fatal. It was found, however, that small quantities of these acids, diluted as they must be in nature, had no effect upon ducks, and birds were able to withstand for a considerable period solutions strong enough to be very sour. In these experiments the characteristic appearances and actions of the duck sickness were not produced. Further, the fact that the sick birds are found in the Tulare basin and elsewhere where there are no smelters, and where there is no other appreciable trade waste of sulphur, serves at once to refute this theory.

Many contended that waste water from the settling ponds of the sugar factories was at the bottom of the trouble. This seemed plausible, as sugar factories are located on each of the three rivers in Utah on whose drainage sick ducks occur. Those who supported this theory attributed the affection either to sulphuric acid used in great quantities in the factories and allowed to escape through drains, or to toxic matter from bacterial agencies generated in the catch ponds that receive the factory drainage. The first supposition has been shown to be untenable. As regards the second, the drainage from these ponds enters the rivers in quantity only during the season that the factories operate in fall. By the time this drainage reaches the marshes in abundance few ducks are dying, and finally the mortality ceases while the mills are still in operation. In 1914, drainage from these settling ponds emptying into the Weber came down with the rise in the water level consequent upon the cessation of general irrigation in mid-September, and there was sufficient toxic matter present to kill large numbers of carp and chubs in the lower channels. Many fish-eating birds (all subject to the duck sickness under proper conditions) were attracted by the abundance of fish floating helpless on the water and fed here until these fish disappeared, but no birds were found sick. During late summer many sick ducks had been found along the lower reaches of the Weber where it spreads out on the lake front, but with this rise in the water, conditions among the ducks improved immediately. As in other cases the fact that the duck sickness occurs in areas where there are no sugar factories serves to militate against the theory that toxic matter in factory drainage is the cause.

In addition to these, the trouble has been ascribed variously to the presence of sewage in the water, parasitic nematodes, arsenic poisoning, and other minor hypotheses, none of which has been found tenable.

THE CAUSE.

In the course of the investigations it has been established definitely that the duck sickness in Utah is caused by the toxic action of certain soluble salts found in alkali. In other words, it may be said that it is due to poisoning by alkali, as that term is used in the West. By actual experiment it has been found that the duck sickness may be caused by the chlorides of calcium and magnesium. Experiments have indicated that other salts may be incriminated in Utah and elsewhere, but this statement is made with reserve, as it has not yet been definitely established.

The Salt Lake Valley is well cultivated and productive and owes its fertility almost entirely to irrigation. In the last 15 years the amount of arable land actually under water has greatly increased, and the stream flow at the river mouths has correspondingly decreased. In midsummer of ordinary years little or no water now passes the irrigation dams on Bear River. The water found at that season in the lower channels comes from such small tributaries as enter below the dams and from seepage from water used in irrigation. Practically the same condition holds in the other streams that flow into Great Salt Lake. Thus irrigation has decreased the amount of water supplying the marshes on the lake front, and the resulting slow drainage induces stagnation over large areas. After June 15, as the spring waters in Bear River recede, great expanses of mud flat are laid bare in the sun. Surface evaporation and capillary attraction rapidly draw the salts held in solution in the mud to the surface and there concentrate them. As the mud becomes drier these concentrates are visible as a white deposit or scale (efflorescence). This in many cases is exposed only an inch or so above the surrounding water level (Pl. I, fig. 2). In the large bays strong winds bank up the water and blow it in across these drying flats. As it advances it takes rapidly into solution the soluble salts, largely sodium chloride, but containing calcium and magnesium chloride also. This inflow of water carries with it quantities of seeds and myriads of beetles, bugs, and spiders, washed out of crevices and holes in the dried and cracking soil. The ducks come in eagerly to feed on this easily secured food and work rapidly along at the front of the advancing water, each bird hurrying to get his fill. Many individuals in this way secure a sufficient quantity of these poisons to render them helpless. As the water recedes again small pools are left in shallow depressions, and other ducks and shorebirds feeding in these are affected.

When this phenomenon was understood the writer was able in many cases to predict that with certain strong winds sick birds would occur in numbers in certain localities, and after a proper interval to send out and have them brought in to the laboratory. The alkaline deposits at the mouth of the large channel known as Brown's Overflow were specially strong in the chlorides of mag-

nesium and calcium. In September great numbers of ducks gathered in here at the eastern end of North Bay to feed and rest. At intervals heavy north winds drove in the water over large areas of dry flats, and after 10 or 12 hours many sick teal would be found. Following each storm sick birds would be abundant for two or three days. The water in pools left as the wind died down was salt and bitter to the taste. The sick birds lay along the mud bars and in the shallows, while numbers of them came over into the overflow to drink the fresh water coming in from the river. Many hid in growths of cockle-burs and rushes on shore, while the open water was dotted with dead bodies. On September 17, 1914, 150 birds were secured here, all that the boat would hold. On September 9, 1916, a heavy storm from the north covered these flats, and the following day 80 ducks were captured, while more were brought in on the days following.

Rains have the same effect, and as here they are usually accompanied by strong winds, the two are conjoined in this destruction of bird life. With light rains small pools form everywhere on the alkali barrens, while with heavier downpours these pools become shallow lakes, the water of which is strong with salts held in solution. Ducks flock in to feed upon floating seeds and insects and upon the fleshy, succulent saltweeds (*Salicornia, Atriplex,* and others) and are affected as described before.

In the fall of 1916 the opening of the hunting season on October 1 was marked by a storm that lasted three days. Spoonbills and teal in great numbers were flying back inland to feed, and a number of sick individuals were found, though most of the sickness on the bays had ceased several days before. Had the bays not been filled by the great supply of fresh fall water, many more would have been seriously affected, as on returning to rest from their feeding expeditions they would have had to drink only the stagnant summer water already more or less charged with salts.

On the Weber River flats the trouble may come from shifting water that floods the flats on the lake front or from general stagnation. The South Channel at present carries more or less running water all summer save in exceptional years. No sick ducks have been known to occur on it. The North Channel is well drained only when the river is high in spring and fall. Here the water lies in shallow isolated ponds or in long connected reaches. Late in summer, surface evaporation from these water areas is very rapid, and the concentration of the salts held in solution is great. At the mouth of the Jordan River the sickness occurs in areas where the water becomes stagnant. Such areas become more pronounced as the lower portion of the marsh near the lake front is approached.

The great prevalence of the duck sickness beginning with 1910 must be attributed to the lessened supply of water in the streams. Coupled with this, however, must be other factors not wholly understood. It seems probable that changes in the water level of Great Salt Lake may be prominent among these. Through the courtesy of Otis West, of the Engineering Department of the Southern Pacific Railroad, there is available a graph showing oscillations in the lake level between the years 1850 and 1914. This chart shows a steady decline in the water level from 1886 to 1902. From 1902 to the beginning of 1906 the water remained about the same, except for the usual rise and fall that occurs each year. A rapid rise began then, so that the lake at its highest point in 1910 was nearly 8 feet above the minimum in 1905. From 1910 there was at first a slight drop, then the level was more or less stable until 1914. In 1914 and 1915 the water lowered again somewhat.

The soil below the surface in the Bear River marshes is strongly saline, and the ground water permeating it is heavily impregnated with salts. Though water in the lower channels and bays was fairly fresh, a hole 10 to 15 inches deep at the water's edge usually yielded an abundance of strongly saline water. The great rise in the lake water would, in this region of low elevations, cause a corresponding rise in the water table of the soil and bring salines in quantities to the surface or near it, perhaps for a considerable distance inland. Thus poisonous elements might be available in abundance in areas where ducks formerly had fed with impunity. The effect of the rising salts in the soil is readily seen in the great areas in which the rushes have been killed in the lower portions of the marshes that border the lake front. In many places there remain of the former growths merely the bulbs with short projecting stubs, or again the plants may be newly dead.

Ducks may establish a slight immunity to the alkali when they gradually become accustomed to it in diluted amounts. In the spring numbers of sick birds were said to be found in the lower channels on Bear River when the birds returned from the south. This was verified when many bodies were seen on the banks of the overflows in May of 1915 and 1916. These birds must have died during the early spring, otherwise the spring water and the ice would have carried them away. Following this there are practically no sick ducks until the first part of July. If the water rises in May or June a good many young avocets and stilts are killed in the salt pools formed on the flats, and occasionally sick coots or young ducks are found. In May, 1916, there was a curious instance of the way birds seemingly exempt from this trouble may be affected. A large flock of cliff swallows was driven down to the flats about Duckville by a heavy

storm that covered the mountains with snow. After the storm the sun came out warm and bright, and a number of the swallows gathered about the shallow pools on the barren flats. Apparently in play, they were forming mud pellets such as they use in building their nests. The strong alkalis concentrated in this surface mud affected many of these birds severely, so that during the next few days I picked up several swallows about the laboratory unable to fly, and there is no means of telling how many escaped unnoticed in the salt grass. The affection in the cases examined was similar to that found in the ducks.

Though mortality among ducks and other birds ceases when the fall water fills the rivers, yet many birds are still more or less seriously affected. During the hunting seasons in the years 1914 to 1916, inclusive, the writer examined many hundreds of ducks as they were cleaned and prepared for the market in the duck houses at the gun clubs on Bear River. In birds examined during the first week or 10 days there was severe irritation in the intestinal tract in almost every case. After October 10, there was a great influx of migrants from the north. These birds were shot in many cases before they had been long on the marshes, but still many of those examined had the intestine much irritated. In cases of severe affection that do not terminate fatally individual ducks use up their stores of fatty tissues while recovering from the duck sickness and become thin and poor in flesh. When shot in this condition they are culled by the duck pickers as unfit to eat. I was told by men familiar with conditions that many more ducks are thrown out now than previous to 1910. Certain observations made by the writer seem to prove this. In 1916 sick ducks were last found in numbers in the eastern end of North Bay. After the hunting season opened a larger percentage of culls was noticed among the birds killed in this area than elsewhere.

REMEDIAL MEASURES.

Fresh water is the only agency that has been found of value in combating the duck sickness. Birds slightly affected, and even many entirely helpless, recover in almost all cases when given plenty of moderately fresh water to drink. With an abundance of good water in the marshes sick ducks are infrequent, as when the bays are well filled and well drained many birds that become affected recover in a few days. For remedial agencies, therefore, measures must be adopted that tend to supply fresh water or to drive ducks out from areas where they are liable to obtain alkalis in harmful quantity. Three methods of treatment that promise success in dealing with this trouble are concerned with (1) increasing summer water in streams, (2) draining affected areas, and (3) collecting sick birds for treatment. These methods as outlined in the following pages will prove applicable also in areas outside of Utah where birds are subject to the duck sickness.

INCREASE OF SUMMER WATER IN STREAMS.

Though an increase in the midsummer water supply in the marshes would go far to alleviate the mortality among the waterfowl, it is obvious that it is difficult to increase the stream flow in the lower courses of the rivers at this season under present methods of cultivation by irrigation. At the time when relief is needed in the marshes the demand for water in the fields and orchards of the uplands is at its maximum. Water is then at a premium, and it is difficult to find any surplus. Only by storing water higher up, in the mountains, and releasing it when needed, could the proper result be obtained. And were this done there might be trouble in passing this extra supply through the irrigation dams below, especially in seasons when the general supply is scanty. More land is being reclaimed and put under water each year, so that the demands made upon the midsummer flow in the rivers are constantly increasing. On Bear River the increased demand is gradually extending to the lower courses of the stream, as pumping stations are being established to raise the water where it is not possible to draw it out directly through canals. While suggested here, this method of meeting conditions is hardly considered feasible, and under such conditions recourse must be had to other means.

DRAINAGE OF AFFECTED AREAS.

Areas where the birds may become poisoned are frequently small or local, and some of them, as pools or channels, may be drained with little effort, and in this way opportunity for affection may be removed. This method has been utilized with success in some small areas. In the Jordan River marshes controlled by the New State Gun Club this means of meeting the situation is particularly applicable. The shooting grounds here have been formed artificially in large part by diverting water from the Jordan River through canals and controlling its flow and direction through the channels by means of well-constructed dams, levees, and head gates. The larger part of this marsh may be dried with little difficulty, and this should be done whenever sick ducks appear, in order to drive the birds out to more favorable localities. In general, it will be found that it is necessary to drain the marshes about July 15, though it may be necessary to draw the water from certain pools during June. When the water used in irrigation is returned to the river, usually about September 20, the marshes may again be allowed to fill. Some areas will remain along the lake front where sick birds may occur, but these are small compared with the entire marsh.

Serious objection has been offered to this plan on the ground that it kills off the duck foods in the marsh and that shooting in the fall is poor in consequence. After examining the marshes here it is considered that this objection is not entirely valid. The main food

supply attracting the ducks apparently is found in the seed heads of the tules or rushes and other similar growth found with them that cover great areas. Draining the marshes at this season should not affect these growths, as the water table will not be lowered far enough to deprive them entirely of water. It is true that it will destroy the leaves and plants of the potato moss (*Potamogeton pectinatus*), as this is entirely an aquatic growth. Tubers of this plant will often remain, however, and it is largely upon these that the ducks feed. In normal circumstances, where water stands in the marshes all summer, hunters usually attract the ducks to certain parts of the marsh by baiting with grain.

At the mouth of the Weber River it may be possible to remedy some of the existing conditions by improved drainage. The North Channel in summer is marked by shallow pools with very slight current, while at either side are smaller bodies of water entirely shut off. It is in these that the ducks die. The South Channel has higher banks and runs directly through the flats; in summer it carries drainage from the irrigation canals. As has been stated, no sick ducks are found along its course. Ditching the course of the North Channel and drawing the water from the shallow pools might aid conditions here, as it would leave less of the dangerous area for birds to use.

On Bear River it is not practicable to use these methods of drainage, because the areas involved are too great and because the land is too near the level of the lake to permit concentrating the water in canals.

CURE OF SICK BIRDS.

Birds with the duck sickness recover in a short time (unless too far gone) when placed on water that is moderately fresh. A large number of ducks were cured by this means at the field laboratory on Bear River, and it has been proved that recovery is permanent. In past years men have been employed to gather and bury the dead birds on the marshes. If they were set to work gathering the sick birds and bringing them in, a large number of ducks could be saved at comparatively small expense. This method is one that is strongly recommended for bettering conditions among the waterfowl in severe outbreaks in Utah and elsewhere.

In the course of the present investigation 1,211 individuals belonging to the seven species of ducks most severely affected were treated in this manner. Of these 284 died and 927 recovered. Among the ducks treated were a large number of very weak birds that were so far along that ordinarily they would have been disregarded. Eliminating these, the ratio of recovery was about 90 per cent of those brought in. Table I shows the number and percentage of recoveries and deaths among individuals treated in the seven important species affected.

TABLE I.—*Record of ducks treated.*

Species.	Number treated.	Died.		Recovered.	
		Number.	Per cent.	Number.	Per cent.
Green-winged teal	604	151	25	453	75
Pintail	361	84	23	277	77
Mallard	112	21	19	91	81
Spoonbill	62	13	21	49	79
Cinnamon teal	43	9	21	34	79
Widgeon	15	2	13	13	87
Gadwall	14	4	28	10	72
Total	1,211	284	23	927	77

Green-winged teal show a low percentage of recovery, but this may be explained by the fact that few of those most severely affected recovered. Among mallards and pintails many individuals are killed by lead poison due to eating shot; these have been eliminated from the table. Besides the species enumerated in the table a certain number of redheads are affected, but these seldom recover. This may be attributed to the circumstance that nearly all are young birds that have no reserves of fat to sustain them during the period when they can not feed.

In the three marsh systems in Utah in which birds are affected a small number of men can care for the sick ducks with little trouble. On both the Jordan and Weber River areas artesian water is available. On Bear River recourse must be had to the water in the main river, which, while far from fresh, has proved pure enough for practical use. By experiment it was found that the water served for this purpose in the channels far down toward the bays as long as it was flowing steadily. In fact, many sick birds congregate in the lower parts of the overflows, and there is no question that a large number of these recover naturally.

The sick birds brought in to the laboratory were confined in pens placed at the river's edge, half on land and half in water, where the water at the lower end of the pens was not more than 18 inches deep. These pens were built 6 feet wide, 12 feet long, and 4 feet high. The framework was made of two by fours, save along the bottom, where one by four material was used. An 18-inch door was placed in the shore end. This frame was covered with wire netting on sides, top, and bottom. To confine the larger ducks, 2-inch mesh wire was used. For teal it was found necessary to use wire with 1-inch mesh, as many individuals were able to escape through wire with a larger opening. When the wire resting on shore did not sink in the mud it was covered lightly with salt grass or rushes to give the ducks a comfortable resting place and to protect their feet. Pens of this size are handled by two men without much trouble and may be moved back and forth as the river rises and falls. Larger

pens would be hard to move, as mud and vegetable matter gather in the water at the lower end and hold firmly.

In regions where artesian wells are utilized for water, posts may be set in the ground to form frameworks for the pens. The top should be covered, otherwise birds still unable to fly may clamber out and escape, only to die in the grass and rushes. Where pens are fixed permanently they should not be too large. As birds recover they begin to fly about and in large pens are liable to injury from striking the wires. It is very difficult to capture and handle ducks properly in large inclosures. The dimensions given above are considered best, though stationary pens may be built in the form of an ell, each arm of which is 12 feet long.

In gathering sick birds it is a good plan to have two men work together. As the ducks are picked up they should be laid in a single layer in the bottom of the boat and covered lightly with rushes. On hot days it is well to sprinkle the rushes with water to aid in keeping the birds cool. If birds are left unshaded the intense heat of the sun will kill many, and they are more readily handled if covered, as then they imagine themselves hidden.

It is necessary to tie active birds in order to keep them in the boat. A soft cotton twine (16-ply) has been found best suited for this purpose. Twines that are hard or too small in size cut the skin and cause discomfort. In tying a duck a loop is thrown around the large bone of either wing near the body and carried across the back. This is tied behind tightly enough to hold the two elbows in position on either side, but not to draw them together behind (Pl. III, fig. 2). In tying the feet, cross them and wrap the string around them twice, and then tie tight enough to hold but not to cut off the blood supply. If the second knot is made a slip knot in each case, as shown in the illustration, the birds may be released readily when desired.

Before placing the ducks in the pens (Pl. IV, fig. 1), each one, if possible, should receive a dose of castor oil, This cleans out the intestinal tract in a short time and aids in alleviating the irritation due to the alkali. The purgative may be administered readily with a medicine dropper, the glass portion of which is 3½ inches long. The duck's bill is held open, and the dropper, filled with castor oil, is inserted well down the gullet past the opening of the windpipe. The bulb is then pressed, the dropper quickly withdrawn, and the bill allowed to close in order that the bird may swallow. The head should be held up for an instant. For teal, one dose (about 1 c. c.) is sufficient. Other ducks should receive two dropperfuls (about 2 c. c.). The ducks may then be placed in the pens.

Teal must be separated from the larger species in confining sick birds or many will be killed, though spoonbills and teal may be kept together without injury. Weaker birds, in addition, must be kept

in separate inclosures from those that are strong and able to move about, otherwise they will be trampled and injured. Weak birds as they grow strong may be transferred to other pens. Birds (especially drakes) that are nearly well often attack those still helpless and injure them severely. The writer has found that gadwalls in particular are bad in this respect. Ducks that have had the rump torn open by gulls or ravens recover readily, but must be kept away from strong individuals, or they will be attacked and killed.

When ducks have fully recovered they may be released. Usually their cure is complete in a week or 10 days. Spoonbills should be released as soon as possible, as often they do not do well on a grain diet. On Bear River they were set free as soon as they began to attempt to use their wings. In many cases birds are unable to fly far when first released, but these ducks seem to regain the use of their wings in a short time and ultimately recover completely. Some, though strong, become unafraid and linger near the duck pens, returning morning and evening when the captive ducks are fed.

The feathers of wild ducks seem to lose their ability to shed water in a very short time. This is true in the dry climate of Utah, at least. Even in the case of strong birds this oiliness is lost in three or four hours of confinement in a boat, so that sick birds placed in the pens become soaked through at once as they swim and dive in the water. Weak birds should be watched, as sometimes they become so water-soaked that they drown. Fairly strong birds are able to come out on the bank after a wetting and dry out their feathers and preen, after which they have no further trouble. Late in September, when the nights were cold and there were heavy frosts, the writer found it best to confine sick birds brought in late in the afternoon or evening in small pens placed in the grass until the following morning. When put in at night, they became wet and soaked and were unable to dry themselves, so that many died from cold. When placed in the water about 9 o'clock the following morning, they became wet but were able to dry themselves in the sun, after which there was little danger of loss from this cause.

The recovery made by weak birds was often surprising. Birds absolutely helpless and unable to support their heads frequently became well and strong again when given proper care. These weak individuals were cared for best in dry pens in the grass or in large trays placed on the floor in the laboratory. Each individual was given a small quantity of water three times a day by means of a long glass funnel or a medicine dropper. The funnel or dropper was placed well down the throat, to prevent water from penetrating the windpipe. In many cases these birds gradually became stronger until they were able to move about, when they were transferred to the stock pens with the other ducks. Pintails especially showed remarkable vitality,

and mallards were not far behind in this respect. Some of the birds treated in this way became tame at once, while others seemed never to lose their sense of fear.

Birds vary somewhat in the degree to which they are affected and in the manner in which they recover. A few pintails and green-winged teal handled during 1916 seemed to suffer some breakdown of the nervous system as a result of the severe paralysis. As these individuals recovered from their helpless condition they had little or no control over their muscular movements, though they seemed normal in other ways. There was a constant trembling of the head, and with any attempt at movement head, wings, and feet were thrown about convulsively. As it raised its head in attempting to drink, such a bird might throw itself completely over, or in trying to swim to shore might dash in circles about the pen, turning over and over. Birds affected in this way, however, were comparatively rare. None of those under observation recovered.

Birds that are seriously sick get very thin as they recover, but soon regain their normal flesh. Sick ducks in captivity should be fed morning and evening. The writer used wheat and barley mixed in equal parts as food for the larger ducks. Teal seldom eat anything but wheat. The grain was placed in shallow wooden troughs 5 feet long, from 4 to 6 inches wide, and 1½ to 2 inches deep. These troughs were placed across the pen a foot or so from the edge of the water. In this way the grain was brought to the notice of the birds as they went in and out of the water. In addition to grain it is well to have a small pan of grit in each pen.

During hot weather half of each pen should be covered with rushes in order to protect captive birds from the sun. Though able to endure intense heat when free, birds may succumb when confined in a narrow space unless protected. On Bear River it was necessary to inclose that part of the pens projecting into the water as a protection against the inroads of the numerous carp. Along the river banks in low water during summer a margin of mud is exposed that separates the roots of the riparian vegetation from the water. This deprives the carp of a large part of their natural feeding grounds, so that grain and excrement about the duck pens proved a great attraction to them and they frequently dug out the mud under an entire pen in the course of a night. Racks 6 or 8 feet long were made of lath sharpened at one end and nailed to crosspieces, with half-inch spaces. With these a fence was built in the water 3 feet beyond the pens and the same distance from either end. This permitted free circulation of water and at the same time kept the carp from digging, as the lath were sunk from 6 to 12 inches in the mud. It is necessary to fill in the duck pens from time to time, as the more active ducks continually dig away the mud from the shore.

RELEASE OF BANDED BIRDS.

Aluminum bands were placed on the legs of about 1,000 ducks that were cured and released at the mouth of Bear River. From these banded birds data have been obtained upon the permanency of the cure and the subsequent longevity of individuals that have recovered. The bands used thus far are of two types: Each bears a number stamped upon one side; on the reverse, one is marked "Notify U. S. Dept. Agr., Wash., D. C.;" the other "Notify Biological Survey, Washington, D. C." These bands are light and in addition are little affected by salt or alkaline waters. Returns have come in at the present time from about 170 of these ducks. Many of these were killed locally, but nearly always under circumstances that indicated that they had fully recovered. Others have come from greater distances. Individual records range west to the Pacific Ocean in California, south to the Mexican border in New Mexico, east to Joplin, Mo., and north into southern Saskatchewan in Canada. Three birds banded in 1914 were killed by hunters during 1916, and another released at the same time was reported in 1917, so that there can be no doubt that the birds treated recovered fully.

Valuable information has been obtained from reports on these banded ducks as to the lines of flight pursued by waterfowl during their migrations. This is of the greatest importance, and it is desired that sportsmen or others who chance to kill these banded birds send immediately full details to the Biological Survey as to the number of the band, together with date and place of capture.

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